I Claim:

1. A method for producing a three dimensional reconstruction with an ultrasound system, the method comprising the steps of:

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(a) transmitting ultrasonic energy at a first frequency band into a subject during said imaging session, said subject being free of added ultrasound contrast agent throughout the entire imaging session;

(b) receiving ultrasonic echo information associated with said transmitted ultrasonic energy;

(c) obtaining from said echo information a plurality of information signals associated with a second frequency band, said second frequency band comprising at least a harmonic band of said first frequency band; and

(d) forming the three-dimensional reconstruction in response to said information signals.

2. The method of Claim 1 further comprising the step of using a transducer selected from the group of: (i) a transducer mechanically scanned in two-dimensions, (ii) a transducer electronically scanned in one-dimension and mechanically scanned in another dimension, and (iii) a transducer electronically scanned in two-dimensions in steps selected from other group of: (a), (b) and both (a) and (b).

3. The method of Claim 1 further comprising the step (e) of displaying an image responsive to said three dimensional reconstruction.

4. The method of Claim 3 wherein the step (e) comprises displaying said image during said imaging session.

5. The method of Claim 3 wherein the step (e) comprises displaying said image after said imaging session.

24 ~~6.~~ The method of Claim 1 wherein the steps (a), (b) and (c) comprise obtaining said information signals associated with at least two planes, wherein said two planes are non-coplanar.

7. The method of Claim 1 wherein the step (c) comprises obtaining said information signals associated with the second frequency band comprising a second harmonic band.

~~8.~~ 26 The method of Claim 1 wherein the step (c) comprises:

(c1) demodulating by a demodulation frequency corresponding approximately to a center frequency of said second frequency band; and

(c2) filtering the output of step (c1) with a low pass filter.

6 ~~9.~~ The method of Claim 3 wherein the step (c) comprises detecting Doppler information as said information signals; and wherein the step (e) comprises displaying said image as a Doppler image selected from the group of: velocity, variance, energy and combinations thereof.

7 ~~10.~~ The method of Claim 3 wherein the step (c) comprises detecting B-mode intensity information as said information signals; and wherein the step (e) comprises displaying said image as a function of said B-mode intensity information.

8 ~~11.~~ The method of Claim 6 ~~9~~ or 7 ~~10~~ wherein the step (e) comprises (e1) summing intensities formatted in a three dimensional grid, said intensities summed along a plurality of lines perpendicular to a viewing plane.

9 ~~12.~~ The method of Claim 8 ~~11~~ wherein the step (e1) comprises applying weighting factors to said intensities.

~~13~~ 10. The method of Claim ~~9~~ 6 or ~~10~~ 7 wherein the step (e) comprises the step (e1) of selecting intensities formatted in a three dimensional grid, said intensities selected along lines perpendicular to a viewing plane.

~~14~~ 11. The method of Claim ~~13~~ 10 wherein the step (e1) comprises selecting as a function selected from the group of: a maximum intensity along each line and a minimum intensity along each line.

~~15~~ 12. The method of Claim ~~9~~ 6 or ~~10~~ 7 wherein the step (e) comprises displaying a surface rendering.

~~16~~ 13. The method of Claim ~~10~~ 7 wherein the step (c) further comprises detecting Doppler information from said echo information, said Doppler information corresponding to information in said first frequency band; and wherein the step (e) comprises displaying said image as a combination of said B-mode image and a Doppler image.

~~17~~ 27. The method of Claim 1 wherein the step (a) comprises transmitting said ultrasonic energy in power bursts, each power burst comprising a respective envelope shape, each envelope shape rising gradually to a respective maximum value and falling gradually from the respective maximum value.

~~18~~ 28. The method of Claim ~~17~~ 27 wherein the step (a) comprises transmitting said ultrasonic energy wherein each power burst comprises a Gaussian envelope shape.

~~19~~ 29. The method of Claim ~~17~~ 27 wherein said power bursts are characterized by a respective frequency spectrum having a respective peak amplitude near the fundamental frequency, said frequency spectrum reduced within a first bandwidth greater than or equal to 5% of the harmonic of the fundamental center frequency by more than 30 dB with respect to the peak amplitude.

20. The method of Claim 19 wherein said power bursts are characterized by said first bandwidth greater than or equal to 15% and said reduction more than 40 dB.

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21. The method of Claim 19 wherein said power bursts are characterized by said first bandwidth greater than or equal to 15% and said reduction more than 50dB.

22. The method of Claim 19 or 20 wherein each frequency spectrum has a second bandwidth associated with said fundamental center frequency and peak amplitude, said second bandwidth being at least about 30% of the respective center frequency at points -6.8 dB with respect to the respective peak amplitude.

23. The method of Claim 3 wherein:

the step (a) comprises said ultrasonic energy characterized by a peak power level near said first frequency band;

the step (c) comprises obtaining from said echo signals said plurality of information signals and a second plurality of information signals associated with said first frequency band;

the step (e) comprises displaying a composite image representing three dimensions, said composite image comprising spatially distinct near-field and far-field regions, said far-field region emphasizing information signals in the first frequency band and said near-field region emphasizing information signals in the second frequency band.

15 ~~24~~. The method of Claim 14 ~~23~~ wherein the receiving step (b) comprises the step of receiving ultrasonic echo information associated with multiple transmit events, such that the first and second frequency bands are associated with different transmit events.

16 ~~25~~. The method of Claim 14 ~~24~~ wherein the step (a) comprises the step of transmitting said ultrasonic energy into the subject in said different transmit events, wherein said

different transmit events comprise a first transmit event focused at a greater depth and a second transmit event focused at a lesser depth.

17 ~~26~~. The method of Claim 14 ~~23~~ wherein the step (e) comprises displaying said near-field and far-field regions in a common imaging mode.

18 ~~27~~. The method of Claim 3 wherein the step (e) comprises displaying a two-dimensional image derived as a function of a viewing angle and said information signals interpolated onto a three-dimensional grid associated with said three-dimensional reconstruction.

19 ~~28~~. The method of Claim 18 ~~27~~ wherein the step (e) comprises the step (e1) of summing said interpolated information signals in said three dimensional grid, said interpolated information signals summed along a plurality of lines substantially perpendicular to a viewing plane, said viewing plane substantially perpendicular to said viewing angle.

20 ~~29~~. The method of Claim 19 ~~28~~ wherein the step (e1) comprises applying weighting factors to said interpolated information signals.

21 ~~30~~. The method of Claim 18 ~~27~~ wherein the step (e) comprises determining an interpolated information signal for each of a plurality of regions in said two-dimensional image as a function selected from the group of: (i) a maximum and (ii) minimum along a line perpendicular to said viewing plane and intersecting said region.

22 ~~31~~. The method of Claim 3 wherein the step (e) comprises displaying said image as a surface rendering.

30 ~~32~~. The method of Claim 1 wherein the steps (a), (b) and (c) comprise obtaining said information signals associated with at least two transmit focal regions for each ultrasound transmit line direction.

31 ~~33~~. The method of Claim 1 wherein the steps (a), (b) and (c) comprise the step (e) of generating information signals associated with a series of planar regions of a volumetric region of the subject.

32 ~~34~~. The method of Claim 31 ~~33~~ wherein the step (e) comprises orienting said planar regions spatially in response to positioning selected from the group of: free hand, monitored free hand, calculated from image motion analysis, and fixture based information.

33 ~~35~~. The method of Claim 1 wherein the step (d) comprises (d1) interpolating said information signals to lines in 3D grid planes.

34 ~~36~~. The method of Claim 33 ~~35~~ wherein the step (d) comprises (d2) interpolating from said lines to a three-dimensional grid.

35 ~~37~~. The method of Claim 33 ~~35~~ wherein the step (d1) comprises interpolating said information signals to an intersection of an arbitrary plane and three-dimensional grid lines.

36 ~~38~~. The method of Claim 35 ~~37~~ wherein the step (d) comprises (d2) interpolating from said intersection to grid positions along said lines.

37 ~~39~~. The method of Claim 1 further comprising the step of (e) quantifying a volume associated with said image.

38 ~~40~~. The method of Claim 37 ~~39~~ wherein the step (e) comprises determining a time sequence of said volume and displaying said time sequence as a graph.

~~41~~. The method of Claim ~~40~~ wherein the step (e) comprises determining a ratio related to volume change over a heart cycle to a maximum volume over said heart cycle.

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40 ~~42~~. The method of Claim 39 ~~41~~ wherein the step (e) comprises displaying said ratio as a function of time.

41 ~~43~~. The method of Claim 39 ~~41~~ wherein the step (e) further comprises determining a mean of said ratio as a function of a plurality of heart cycles.

42 ~~44~~. The method of Claim 37 ~~39~~ wherein the step (e) comprises the steps of (e1) determining a region of interest of said image and (e2) summing volumes of each volumetric element within said region of interest.

43 ~~45~~. The method of Claim 42 ~~44~~ wherein the step (e2) comprises subtracting volumes associated with one region from volumes associated with another region.

44 ~~46~~. The method of Claim 42 ~~44~~ wherein the step (e1) comprises using automatic border detection.

45 ~~47~~. The method of Claim 42 ~~44~~ wherein the step (e1) comprises selecting said region of interest manually.

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48. The method of Claim 1 wherein the step (c) comprises generating said information signals as scan converted frames of data representing two-dimensional images; and the step (d) comprises forming said three-dimensional reconstruction in response to said frames of data.

47 ~~49~~. The method of Claim 1 wherein the steps (a), (b) and (c) comprise generating said information signals as groups of data representing scan lines; and the step (d) comprises forming said three-dimensional reconstruction in response to said groups of data.

49 ~~50~~. The method of Claim 1 wherein the step (a) is responsive to a gating signal.

23 ~~51~~. The method of Claim 3 wherein the step (e) comprises displaying a sequence of images as a function of time and responsive to said three-dimensional reconstruction.

49 ~~52~~. The method of Claim 1 wherein the step (a) comprises transmitting said energy into said subject in a transmit beam having an elongated high power region by focusing at least first selected frequency components from at least selected transducer elements at a first range and focusing at least second frequency components from at least selected transducer elements at a second range.

50 ~~53~~. The method of Claim ~~52~~ 49 wherein the step (a) comprises the step of phasing a plurality of transmit waveforms to form the transmit beam.

51 ~~54~~. The method of Claim ~~53~~ 50 wherein the plurality of transmit waveforms comprises a central transmit waveform associated with a central one of the transducers, wherein the central transmit waveform comprises a lower frequency component and a higher frequency component, and wherein the lower frequency component of the central transmit waveform occurs earlier in time than the higher frequency component of the central transmit waveform.

52 ~~55~~. The method of Claim ~~52~~ 49 wherein the first range is greater than the second range, and wherein the first selected frequency components are characterized by a higher power level than the second selected frequency components.

53 ~~56~~. The method of Claim ~~52~~ 49 wherein the step (a) comprises the step of varying apodization of the transducer elements to achieve more nearly uniform ultrasonic energy levels at the first and second ranges.

~~57~~. 54 The method of Claim 1 wherein the step (a) comprises transmitting said energy into said subject in a transmit beam having a line focus.

~~58~~. 55 The method of Claim ~~57~~ 54 wherein the step (a) comprises phasing a plurality of transmit waveforms to form the line focus for the transmit beam.

~~59~~. 56 The method of Claim 1 wherein the step (a) comprises transmitting said energy substantially focused in an azimuthal direction and divergent in a elevational direction.

~~60~~. 57 The method of Claim ~~59~~ 56 wherein the step (a) comprises transmitting said energy from a transducer selected from the group of: a single element transducer rotatable in one-dimension, a linear array comprising a lens divergent in one dimension and a two-dimensional array.

~~61~~. 58 The method of Claim ~~59~~ 56 wherein the step (d) comprises acoustically summing along the elevational direction for each of a plurality of ranges along each of a plurality of azimuthal scan line.

62. A method for calculating a volume quantity with an ultrasound system, the method comprising the steps of:

(a) transmitting ultrasonic energy at a first frequency band into a subject during said imaging session, said subject being free of added ultrasound contrast agent throughout the entire imaging session;

(b) receiving ultrasonic echo information associated with said transmitted ultrasonic energy;

(c) obtaining from said echo information a plurality of information signals associated a second frequency band, said second frequency band comprising a harmonic band of said fundamental frequency band; and

(d) displaying a volume quantity associated with said information signals.

63. The method of Claim 62 wherein the step (d) comprises the steps of (e) determining a region of interest of said image and (f) summing volumes of each volumetric element within said region of interest.

64. The method of Claim 62 wherein the step (d) comprises displaying said volume quantity during said imaging session.

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65. The method of Claim 62 wherein the step (d) comprises displaying said volume quantity after said imaging session.

66. The method of Claim 63 wherein the step (e) comprises using automatic border detection.

67. The method of Claim 62 wherein the step (d) comprises determining a time sequence of said volume.

68. The method of Claim 67 wherein the step (d) comprises determining a ratio related to volume change over a heart cycle to a maximum volume over said heart cycle.

69. The method of Claim 68 wherein the step (d) further comprises determining a mean of said ratio as a function of a plurality of heart cycles.

70. The method of Claim 62 wherein the step (d) comprises calculating said quantity from said information signals, said information signals comprising line data.

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71. The method of Claim 62 wherein the step (d) comprises calculating said quantity from said information signals, said information signals comprising three-dimensional grid data.

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~~72~~. A method for producing three dimensional images with an ultrasound system, the method comprising the steps of:

(a) transmitting ultrasonic energy in power bursts into a subject, each power burst comprising a first center frequency and a respective envelope shape, each envelope shape rising gradually to a respective maximum value and falling gradually from the respective maximum value;

(b) receiving ultrasonic echo information associated with said transmitted ultrasonic energy;

(c) obtaining from said echo information a plurality of information signals associated with a second frequency band, said second frequency band comprising a harmonic band of said fundamental frequency band; and

(d) displaying an image representing three dimensions and responsive to said information signals.

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~~73~~. The method of Claim ~~72~~ wherein the step (a) comprises transmitting said ultrasonic energy wherein each power burst comprises a Gaussian envelope shape.

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62 ~~74~~. The method of Claim 59 ~~72~~ wherein the step (d) comprises displaying said image at a time selected from the group of: during and after said imaging session.

63 ~~75~~. The method of Claim 59 ~~72~~ wherein the step (c) comprises obtaining said information signals associated with at least two non-coplanar planes.

64 ~~76~~. The method of Claim 59 ~~72~~ wherein said power bursts are characterized by a power level at a harmonic bandwidth greater than or equal to 5% of the harmonic of a fundamental center frequency which is reduced by at least 30 dB with respect to ultrasonic power in the power burst at a fundamental center frequency.

67 ~~77~~. The method of Claim 69 ~~72~~ wherein the step (a) comprises transmitting into said subject during an imaging session, said subject being free of ultrasound contrast agent throughout the entire imaging session.

70 ~~78~~. The method of Claim 59 ~~72~~ further comprising the step of (e) providing an ultrasound contrast agent within said subject.

71 ~~79~~. The method of Claim 70 ~~78~~ further comprising the step of (f) quantifying a volume associated with a region of interest in said image, said region selected from the group of: a tissue boundary, edges of a chamber filled with contrast agent loaded fluid, and edges of a tissue region substantially without contrast agent loaded fluid.

68 ~~80~~. The method of Claim 67 ~~77~~ wherein said power bursts are characterized by a power level at a harmonic center frequency which is reduced by at least 40 dB with respect to ultrasonic power in the power burst at a fundamental center frequency.

69 ~~81~~. The method of Claim 68 ~~80~~ wherein said power level is reduced by at least 50 dB.

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72 ~~82~~. The method of Claim ~~72~~ 59 further comprising the step (e) of quantifying a volume associated with a tissue boundary region of interest in said image.

~~83. An ultrasound apparatus for generating a three dimensional reconstruction, said apparatus comprising:~~

~~a transducer;~~

~~a transmit beamformer operatively connected to said transducer for transmitting ultrasonic energy into a subject during an imaging session, said subject being free of added ultrasound contrast agent throughout the entire imaging session;~~

~~a receive beamformer operatively connected to said transducer and configured to obtain a plurality of information signals associated with a harmonic frequency band, said harmonic frequency band comprising harmonics of a fundamental frequency band transmitted into a subject; and~~

~~wherein the three-dimensional reconstruction is responsive to said information signals.~~

74 ~~84~~. The apparatus of Claim ~~83~~ 73 wherein said transducer comprises a transducer selected from the group of: (i) a transducer mechanically scanned in two-dimensions, (ii) a transducer electronically scanned in one-dimension and mechanically scanned in another dimension, and (iii) a transducer electronically scanned in two-dimensions.

75 ~~85~~. The apparatus of Claim ~~83~~ 73 further comprising a display.

76 ~~86~~. The apparatus of Claim ~~83~~ 73 wherein said three-dimensional reconstruction comprises a regularly spaced three-dimensional grid of data samples.

77 ~~87~~. A method for producing a three dimensional reconstruction with an ultrasound system, the method comprising the steps of:

(a) transmitting ultrasonic energy at a fundamental frequency into a subject in a transmit beam having an elongated high power region by focusing at least first selected frequency components from at least selected transducer elements at a first range and focusing at least second frequency components from at least selected transducer elements at a second range;

(b) receiving ultrasonic echo information associated with said transmitted ultrasonic energy;

(c) obtaining from said echo information a plurality of information signals associated with harmonics of the fundamental frequency band; and

(d) forming the three-dimensional reconstruction in response to said information signals.

78 ~~88~~. The method of Claim ~~87~~ 77 wherein the step (a) comprises the step of phasing a plurality of transmit waveforms to form the transmit beam.

79 ~~89~~. The method of Claim ~~88~~ 78 wherein the plurality of transmit waveforms comprises a central transmit waveform associated with a central one of the transducers, wherein the central transmit waveform comprises a lower frequency component and a higher frequency component, and wherein the lower frequency component of the central transmit waveform occurs earlier in time than the higher frequency component of the central transmit waveform.

80 ~~90~~. The method of Claim ~~87~~ 77 wherein the first range is greater than the second range, and wherein the first selected frequency components are characterized by a higher power level than the second selected frequency components.

81 ~~91~~. The method of Claim ~~87~~ 77 wherein the step (a) comprises the step of varying apodization of the transducer elements to achieve more nearly uniform ultrasonic energy levels at the first and second ranges.

82 ~~92~~. The method of Claim ~~87~~ 77 wherein the step (a) comprises transmitting during an imaging session, said subject being free of ultrasound contrast agent throughout the entire imaging session.

83 ~~93~~. The method of Claim ~~87~~ 77 further comprising the step of providing an ultrasound contrast agent.

84 ~~94~~. The method of Claim ~~87~~ 77 wherein the step (d) comprises interpolating from said information signals onto a regularly spaced 3D grid.

85 ~~95~~. The method of Claim ~~87~~ 77 wherein the step (d) comprises generating a two-dimensional representation of said three-dimensional reconstruction.

86 ~~96~~. A method for producing a three dimensional reconstruction with an ultrasound system, the method comprising the steps of:

(a) transmitting ultrasonic energy at a fundamental frequency into a subject in a transmit beam having a line focus;

(b) receiving ultrasonic echo information associated with said transmitted ultrasonic energy;

(c) obtaining from said echo information a plurality of information signals associated with harmonics of the fundamental frequency band; and

(d) forming the three-dimensional reconstruction in response to said information signals.

87 ~~97~~. The method of Claim ~~96~~ 86 wherein the step (a) comprises phasing a plurality of transmit waveforms to form the line focus for the transmit beam.

88 Add ~~98.~~ The method of Claim ~~96~~ ~~106~~ 86 wherein the step (d) comprises interpolating from said information signals onto a regularly spaced 3D grid.

89 ~~99.~~ The method of Claim ~~96~~ ~~106~~ 86 wherein the step (d) comprises generating a two-dimensional representation of said three-dimensional reconstruction.

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